Thermal and electrical interfacial layer of graphene for high performance point emitter

Jeong Seok Lee, Hyelynn Song, Yong Hyup Kim

Seoul National University, Sillim-dong, Seoul, 151-742, Korea
misty7@snu.ac.kr

Abstract

With the superior material properties and geometric benefit of high aspect ratio, various researches have been performed to fabricate carbon nanotube (CNT) point emitters which are capable of providing low turn-on voltage, high current density and long-term operating stability [1]. Especially, extremely high field emission current density of the point emitters plays an essential role in generating sufficient power sources for microwave amplifier tubes, high-resolution electron-beam instruments and Terahertz and X-ray sources [2]. Moreover, one-dimensional geometry of carbon nanotube point emitter can reduce the operating voltage in the applications due to amplification of field enhancement.

However, it is unavoidable in the process that thermal and electrical contact resistances between metal and carbon nanotube would degrade the emission performance, which issues also have been brought up through past studies [3]. Various efforts have been devoted to improving the electric and thermal contacts between metal and carbon nanotube, including the increase of contact surface area using ultrasonic bonder, the reduction of contact resistances by the aid of carbon layer deposition using EBID (electron beam induced deposition equipment) [4] or the formation of graphitic layer via heat treatment at temperature above 880 K [5]. The methods could improve the contact resistances, however, they require high temperature or additional complicated treatments.

In the present study, we have used graphene as an interfacial layer between metal and CNT to improve the contact resistances. Single layer graphene has been proven to show remarkable electron mobility (~150,000 cm^2/V•s) and thermal conductivity (~3100-5300 W/m•K). Since graphene basically consists of the same material of carbon as CNT and has a similar level of work function (~4.5 eV), our approach can have great advantages of electric and thermal interfaces between these low dimensional carbon materials. With superior electric and thermal contact characteristics created by graphene layer, the present point emitter shows extremely high current density of 2300 A/cm^2, net current of 16 mA and stable, long-term operation over 10 hours.

References

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Figure 1.

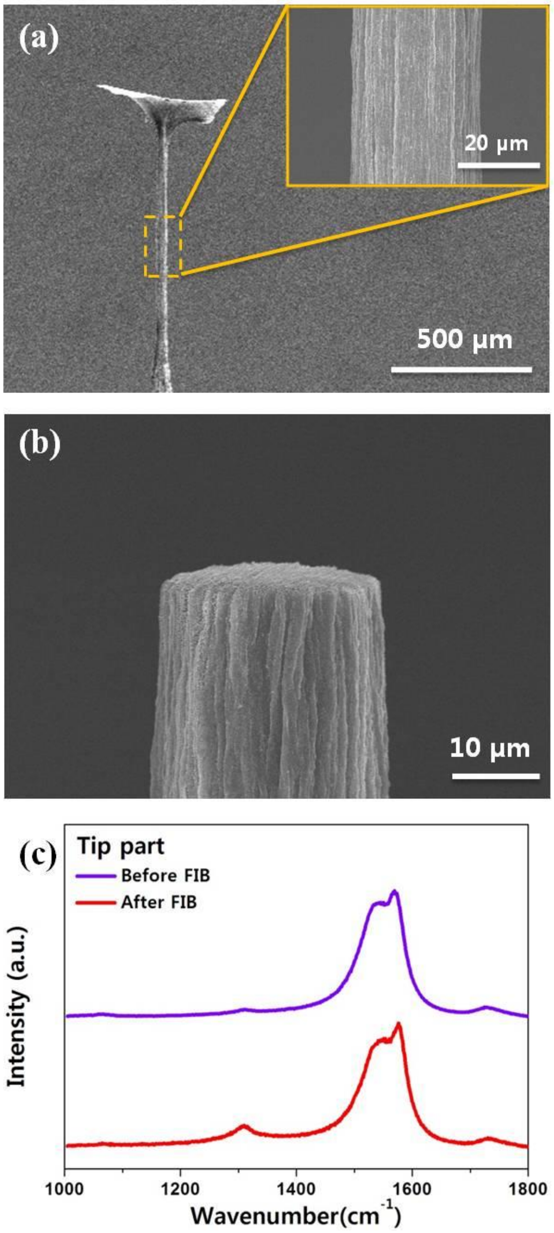

Fig 1. (a) Scanning Electron Micrograph of the point emitter, this is constituted by aligned carbon nanotubes with one direction. (b) Scanning electron micrograph of the emitter with the nail head removed by FIB treatment. (c) Raman spectrum at 532 nm for the cross section of carbon nanotube point emitter of two cases, before FIB and after FIB treatment.

Figure 2.

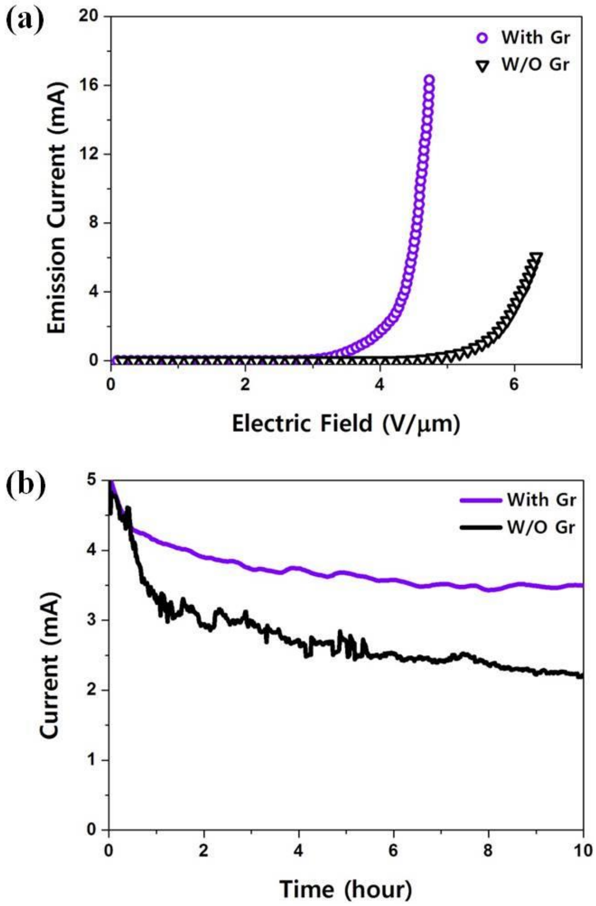

Fig 2. (a) I-V plots of point emitter with graphene and without graphene. (b) Field emission stability test of the emitter with graphene and without graphene.